ECL 271

IT'S THE PITS

One afternoon in the middle of February, my phone rang. I answered it to hear: "Dr. MacGowan?* I'm Bill Hunger at Lodgepole Construction. We recently installed a welded piping system, identical with some earlier ones, but this latest one leaks. We're baffled as to why. Can you help us?"

I responded that I would try. We agreed to meet the next morning at his office at Lodgepole Construction Company.

C. O. SMITH

*Names, but not facts, have been changed.

After Bill and I sat down with cups of coffee, he told me his tale. Lodgepole had installed a Type 304 stainless steel pipeline for B. A. Billy Chemical Co. This involved several hundred feet of line intended to carry acetone. The installation had been done the previous August/September. At some point, there had been a pressure test of the system at 225 psi (1.55 MPa) and a few leaks had been found, not at all uncommon. Lodgepole had made the necessary repairs and the line was retested in mid-November. There were no leaks at 225 psi (1.55 MPa). When B. A. Billy started to use the line with acetone in the middle of February (a day or two before Bill Hunger called me), many leaks were noted, perhaps as many as 50 to 75. Essentially all of these leaks were in the vicinity of welds. What was really upsetting to all concerned was that Lodgepole had previously installed essentially identical systems at B. A. Billy with no leakage problems. The only obvious difference from previous installations was that B. A. Billy had put the earlier lines into service within a week or two of completion whereas this line had been idle for about 3 months before startup.

I asked if they were certain that the stainless steel was indeed Type 304. Bill said that, so far as he knew, it was. He gave me the phone number of Monty Weed, a project engineer with B. A. Billy, and suggested that I talk with him directly.

I also asked about the welding practice. Bill Hunger gave me a copy of Lodgepole's standard procedure (Exhibit A-1). He also told me that the two tensile tests required by that procedure had been made by Bob Stonehouse with failures in the parent metal at ultimate stresses of 81,400 (561) and 82,900 psi (572 MPa). I knew Bob well and had complete trust in his test results.

When I inquired about the operating pressure, Bill said he wasn't sure but knew it was well below the 225 psi (1.55 MPa) used for the pressure testing. He also commented that the pressure testing was done using well water available at the site. In response to a question about an analysis of the water, he said he did not know but was sure that Monty Weed would know. He was also under the impression that the line had been drained after the pressure testing in mid-November.

The only additional information which he could give me at that point was a short, cut out section of the pipeline with a weld in the middle of the section. Leaks had been observed in the vicinity of this weld.

GTAW (MANUAL GAS TUNGSTEN-ARC WELDING)

WELDING PROCESS

Stainless metal welded by the Heliarc process.

BASE METAL

Type 304 stainless, 6" Sch. 40 pipe, specification SA-312 to be used in this test, covered by P No. 8, Group No. 1, with a specified minimum tensile of 75,000 PSI.

FILLER METAL

Filler metal analysis A No. 7, 3/32" dia. wire, filler metal No. F5, SFA Specification SFA5.4.

POSITION OF WELD

The welding to be done in the 6 G position, uphill.

PREHEATING

None.

POST WELD HEAT TREATMENT

None.

BACKING

No backing ring, ARGON PURGE.

PREPARATION OF BASE METAL

The pipe edges shall be ground or machined to form a $75^{\circ} \pm 5^{\circ}$ groove as per sketch on WPS 4-8-3. Edges shall be clean and free from foreign material.

ELECTRICAL CHARACTERISTICS

Current DC, Polarity, straight.
Amps 60 approximately with 12-14 volts.

WELDING TECHNIQUE

With a gap of 1/32" and a land of 1/32" + 1/32"-0", the first pass shall be made without the use of filler metal. Successive passes to use filler metal. The inside of the pipe shall show complete 100% penetration with a convex bead of uniform size around the circumference, approx. 1/32" above the inside wall of pipe. Successive passes of the weave type shall show no undercutting of the side walls of the pipe groove, the last pass to form a reinforcement of 1/16" maximum. No undercutting is permitted.

CLEANING

None except as noted below in defects.

DEFECTS

Any cracks or weld imperfections shall be ground out to good metal before depositing successive passes, wire brushed with stainless brushes to remove any foreign material from the grinding process.

TESTS REQUIRED

Two (2) Reduced Section Tests
Two (2) Face Bends
Two (2) Root Bends

IT'S THE PITS (Part B)

Before calling Monty Weed, I took a look at the section of pipe which I had brought with me. I thought I would be inclined to call it tube rather than pipe since it was 3 in (75 mm) outside diameter with a 1/8 in (3.1 mm) wall thickness. Visual examination of the weld indicated an apparently sound, proper weld. I noted a reddish-brown discoloration inside the tube along the entire length of the section and over a peripheral angle of about 120°. There were some features on the inside surface of the tube which suggested pitting had occurred.

When I talked over the telephone with Monty Weed, he said that, so far as he knew, the tubing was Type 304 stainless steel. He was positive that was what the invoice said and he was trying to reach a representative of the steel supplier to confirm that the invoice was correct, i.e., that Type 304 had indeed been shipped.

Monty was quite certain that the system had been drained after pressure testing. When I asked if the well water had ever been analyzed for content, he said that it never had. He further seemed to feel that there was no need to do so, it was just ordinary well water. I had the feeling that he thought it was ridiculous to even think that well water could have any effect on stainless steel. I also had the feeling that he was certain that Lodgepole Construction had done something wrong in the installation and was thus responsible.

It was obvious that the problem had not been resolved. My next step was to cut a small sample from the section of tubing. This sample included some of the weld deposit and the heat affected zone (HAZ) on each side of the weld. This sample was small enough to go into a scanning electron microscope (SEM).

Use of the spectrographic analyzer in the SEM indicated that the parent metal contained iron, chromium, and nickel in about the correct proportions for Type 304 stainless steel. The weld deposit showed the same elements although the nickel content was a little lower.

Examination of the sample using the SEM gave clear evidence of pitting as indicated by Exhibits B-1 through B-6. Pits were observed in the weld deposit, the HAZ, and the parent metal close to the HAZ. Although the depths of the observed pits were not measured (and thus were unknown), there was no evidence of complete penetration in the region examined under the SEM. This sample, however, represented less than 1/10 of the length of the weld around the circumference of the tube.

Although I would have liked to have an analysis of the well water, within a week of his call, I was ready to go back to Bill Hunger with an opinion of what caused the leakage in this piping system. This opinion was not 99% certain, as it did rely on some factors which were not clearly established, but I believed it was well above the speculation category.



Exhibit B-1: SEM photograph of specimen (as-received) at the outside edge of the HAZ showing initiation of pitting. (1000X)



Exhibit B-2: SEM photograph of specimen (as-received) at the edge of the weld deposit in the HAZ. Pitting is obvious. (1000X)



Exhibit B-3: SEM photograph of specimen (electrolytic polish) in the weld deposit at the edge of the weld deposit. Polish cleaned the surface but not inside the pits. (1000X)

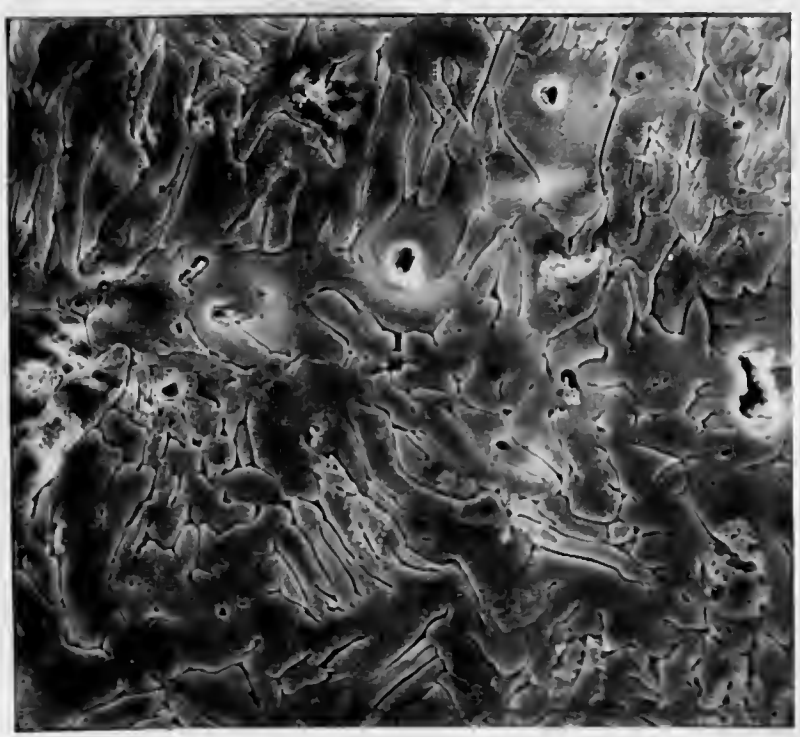


Exhibit B-4: SEM photograph of specimen (heavy electrolutic polish) in the weld deposit. Pitting appears to have initiated but some of these "holes" may be inclusions. (1000X)



Exhibit B-5: SEM photograph of specimen (heavy electrolytic polish) in the weld deposit at the edge of the HAZ. (1000X)

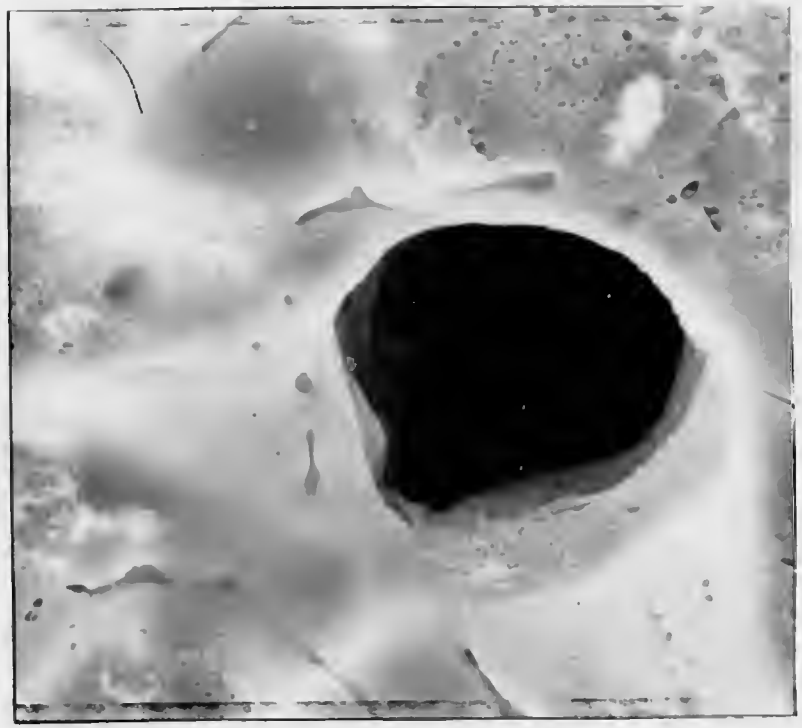


Exhibit B-6: Pit at the location shown in Exhibit B-5. Depth of pit is not known. (3000X)

IT'S THE PITS (Part C)

Comments

Corrosion data indicate there should be no problem of attack on Type 304 austenitic stainless steel by acetone. Experience in this plant with similar earlier systems supports this.

It is reasonable to assume the parent metal was Type 304, as alleged, and that a suitable welding rod was used. Despite the difference in size between the tube used here and 6 in (152 mm), Schedule 40 pipe, following the terms of Exhibit A-1, so far as they apply, should be appropriate.

It is known that pitting of austenitic stainless steels is a strong possibility under exposure to water containing dissolved chlorine and oxygen, especially if the water is stagnant. Althouth no analysis was performed on the well water used for pressure testing, it is highly probable that oxygen and chlorine would be found.

The reddish-brown appearance observed on the inside of the tube is sometimes seen on austenitic stainless steels exposed to stagnant water over an extended period. In such a situation, however, there is usually a general, more-or-less uniform, relatively slow attack. Another possible source of discoloration might be precipitation of iron compounds from stagnant water.

Opinion

The observed leaks undoubtedly came from pits which completely penetrated the tube wall. Most of these pits were close to the junction between the weld deposit and the HAZ. Welding would leave some residual stress in this region and increase the susceptibility to pitting. This does not imply error on the part of the welder, nor does it imply any deficiency in the tubing used for the system.

One would expect oxygen to be dissolved in the water used for pressure testing. The presence of dissolved chlorine is highly likely. It is highly likely that the system was not drained, at least not completely, after pressure testing. This would leave stagnant water containing dissolved oxygen and chlorine in contact with a stainless steel tube which was relatively susceptible to pitting. If there had been "no" delay between pressure testing and putting the system into service, there should have been no problem.

Obviously, the leaks must be repaired. There will be weak spots in the system where pitting has started, but has not penetrated through the tube wall. Presumably it is more economical to repair these if they develop rather than replace the entire system.

IT'S THE PITS

This involves a problem in corrosion, a pervasive problem which is often affected by a number of subtle changes in the specific application.

Part A gives some information but does leave the student in the situation of formulating a "best guess." Initially assigning Part A only, give students an opportunity to (1) analyze a situation, (2) make some decisions as to important aspects and factors, and (3) develop a plan action of actionwhich should allow them to determine a solution and make recommendations.

Part B tell what was actually done (and some students may have superior suggestions which are workable). Whether Parts A and B are given in separate assignments or given together as one assignment, having Part B in hand students should be in a position to formulate a "good" solution as Dr. MacGowan thought he could do. Presumably what is wanted now is (1) the most logical explanation for the development of leaks, (2) an indication of necessary action, (3) a determination of responsibility (The repairs must be paid for!), and (4) recommendations for avoiding this problem in any future installations. Relative to the fourth item, it is possible that Lodgepole Construction may well be making similar installations for other companies as well as for B. A. Billy. One might explore the applicability of Exhibit A-1 (6 in, Schedule 40 pipe) to 3 in tube. Is it proper to use an SEM for alloy analysis as compared with wet chemical analysis, or other analytical methods?

Part C gives the substance of Dr. MacGowan's report to Bill Hunger. If there is a better solution proposed, it should be welcomed!

It appears that a part of this system failure was a consequence of an administrative decision, i.e., startup was delayed (presumably for good reasons) and no thought was given to the possibilities (however subtle) of the failure which resulted.